ACCELERATOR EXPERIMENT:    Determination of the High-Field Vertical Beam
Emittance of the Booster

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A calibrated vertical 3-bump (BEXBMP) has been used to determine the
vertical size of the booster beam near extraction. These measurements were
taken under operating conditions for the cases of single-turn kicker and
two-turn ORBUMP injection. Each of the two turns was also investigated
individually.

DATA:

The results of the measurements are shown in Figure 1. The ordinate
is the fraction of the booster beam surviving after the 3-bump has been used
to scrape the beam against the MP01 septum. The abscissa is the 3-bump
peak detector read-back which is proportional to the amplitude of the beam
displacement. The constant of proportionality between the read-back and the
displacement was determined by raising the MP01 septum 0.25" and increasing
the bump amplitude to compare losses with the case of the unmoved septum
($73 \pm 3\mu A$ corresponds to .25" = 6.35 mm.)

The maximum displacement of the half-sinewave 3-bump was set to occur 2 ms
before the normal extraction time (TEXBMP = 30800). The transmission plotted
in Fig. 1 is defined to be the charge at the normal extraction time (35000 BCP)
divided by the charge ~ 5 ms before extraction (30000 BCP). For 13 booster
batches, the unscraped intensity was $1.26 \times 10^{13}$ for the two-turn ORBUMP
injection (.78 for the first and .73 for the second turn when investigated
individually) and $7.0 \times 10^{13}$ for the single-turn kicker injection.

The measured transmission values seem to fluctuate in those cases when the surviving beam intensity is less than 1 or $2 \times 10^{11}$ protons per batch. Consequently, a straight line extrapolation has been used to estimate the BEXBMP displacement necessary to completely destroy the beam. The measurement fluctuations are presumably due to low-intensity feedback difficulties in the booster low level RF system.

Measurements taken with the booster extraction septum magnet (MP01) on and off indicated that its stray magnetic field did not affect the data reported here.

INTERPRETATION:

As can be seen from the raw data, all four of the cases considered indicate some beam loss as soon as BEXBMP is raised above the nominal setting of 40.1. Figure 2 shows the vertical beam half-width w as a function of the fraction of beam entirely contained within $\pm$ w for the two extreme cases: single-turn kicker and two-turn ORBUMP.

The emittance $\epsilon = \frac{\pi w^2}{\beta}$, ($\beta$ = 20.3 m) is plotted in Figure 3 against the same abscissa as in Figure 2. Also shown in Figure 3 are four reference values for the vertical emittance.

The first reference value corresponds to the emittance one would expect by scaling the injection emittance determined by the linac of $11\pi$ mm-mr from 644 MeV/c to 8.8 GeV/c. The second reference value is the vertical acceptance $\frac{R^2}{\beta} = 11\pi$ of the booster caused by the restricted clearance at MP01 scaled in the same way as the first reference value.

The third and fourth reference values are related to the acceptance of the main ring. The third marker is the maximum booster emittance the main ring could accept assuming a $\pm$ .5" vertical clearance for $\beta$ = 100 m. The

fourth reference value is based on a measurement of the emittance of the main ring at 300 GeV by Gene Fisk.  That is, a vertical emittance at 300 GeV of 0.06 $\pi$ implies an emittance at 8.89 GeV/c injection of 1.96 $\pi$ mm-mr.  This corresponds to two-turn ORBUMP injection into the booster.

Since the fourth reference value based on an emittance measurement is larger than the third value based on the $\pm$ .5" aperture assumption, one must conclude either that the beam is blowing up slightly in the main ring or that the restricting aperture of the main ring is slightly larger than $\pm$ .5".

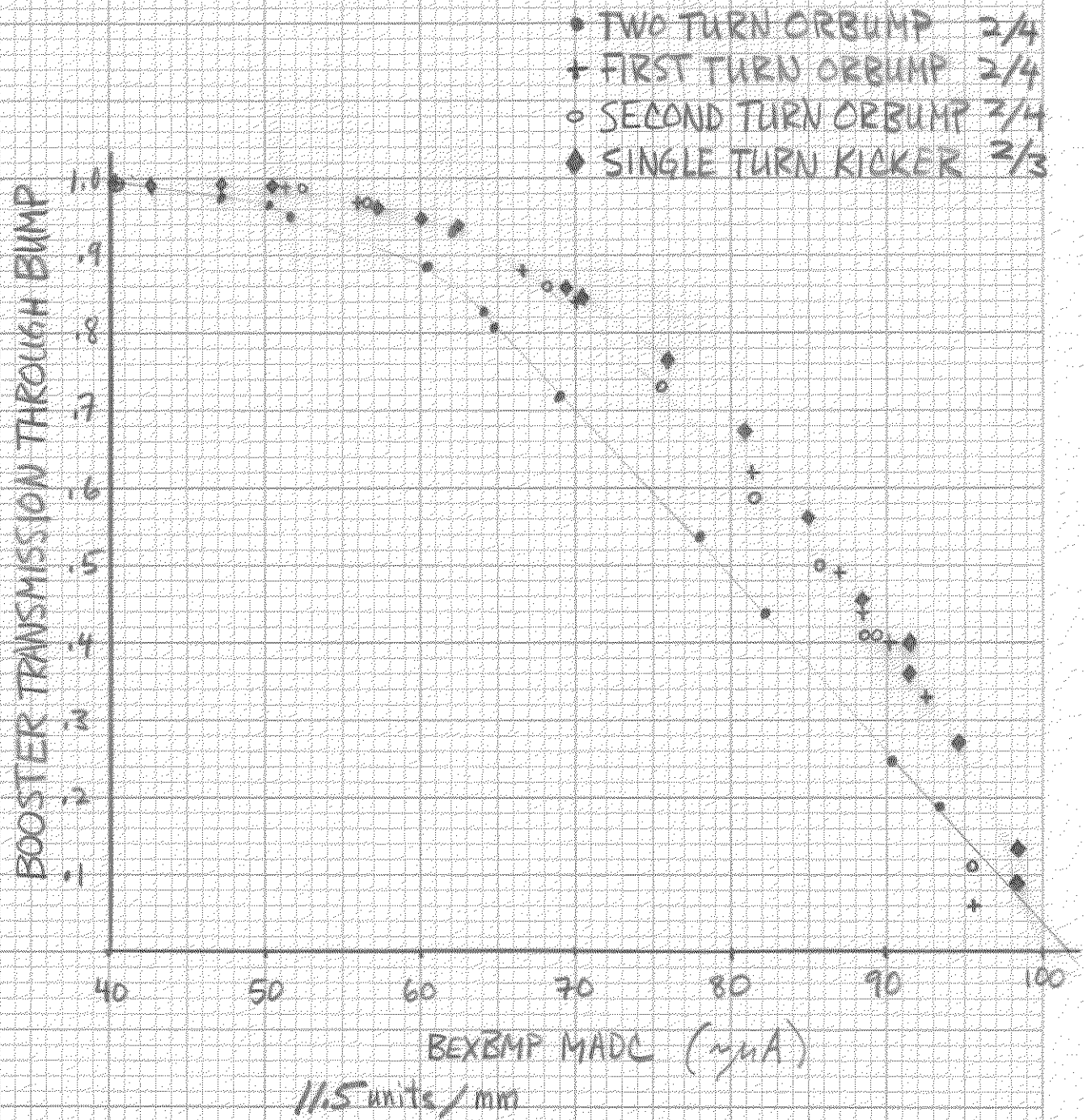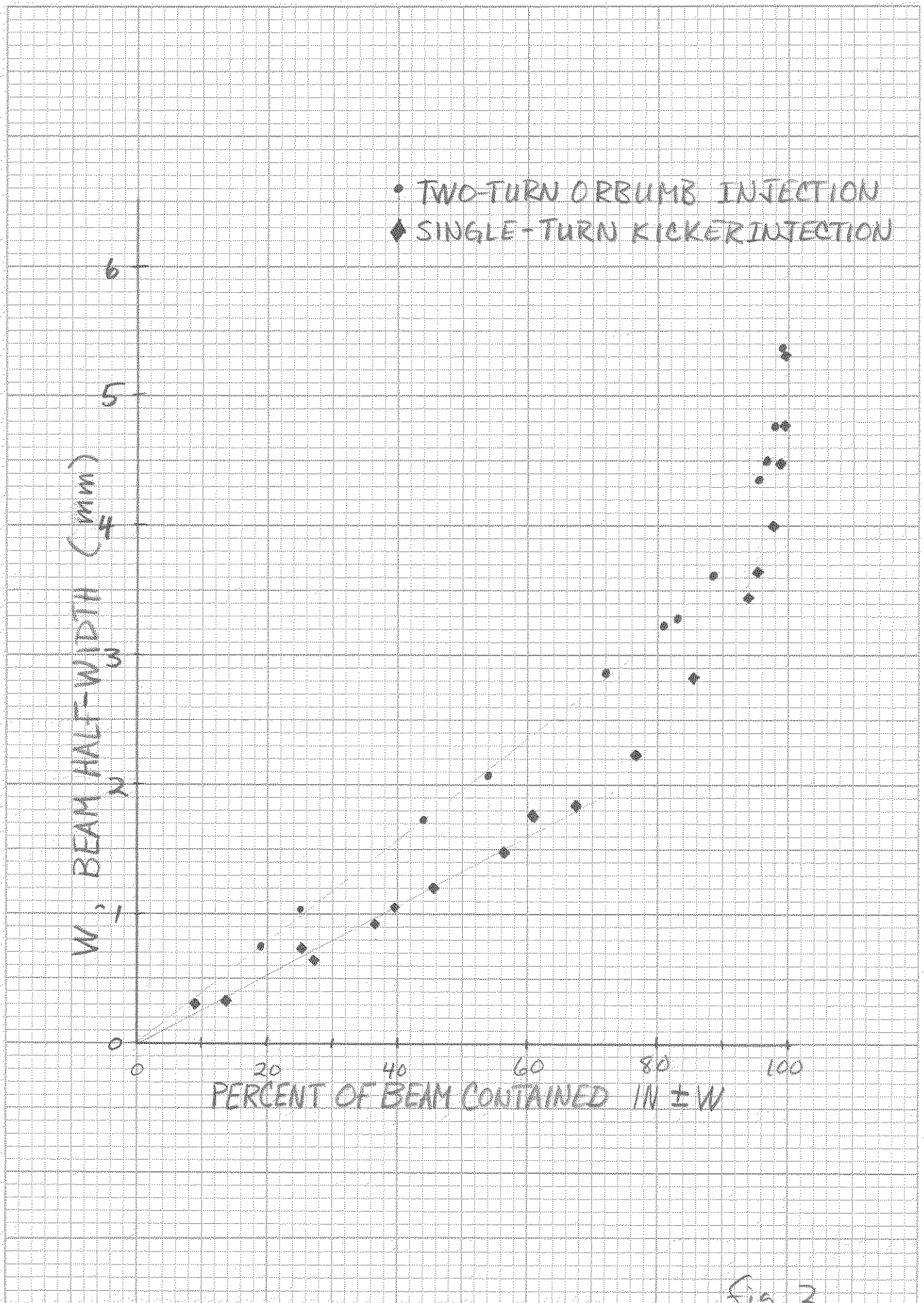Thanks to Ben Prichard for risking life and limb to help calibrate the BEXBMP.

RAW DATA



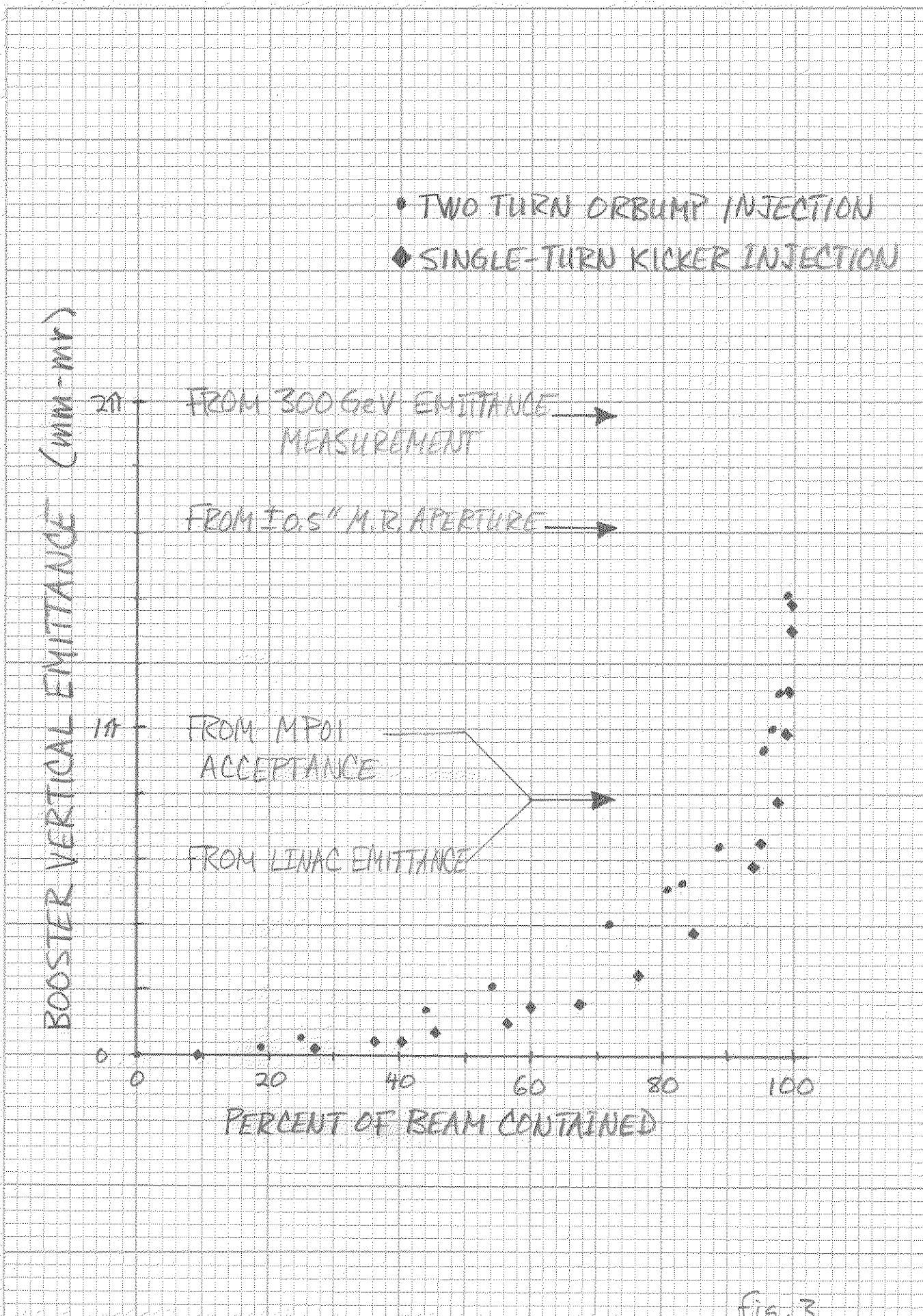TWO TURN ORBUMP    2/4
FIRST TURN ORBUMP   2/4
SECOND TURN ORBUMP  2/4
SINGLE TURN KICKER   2/3

BOOSTER TRANSMISSION THROUGH BUMP

BEXBMP MADC (μA)

11.5 units/mm

fig 1

Fig 2

fig. 3